Profit and yield of tillage in cotton production systems

R.A. Buman, B.A. Alesii, J.F. Bradley, J.L. Hatfield, and D.L. Karlen

ABSTRACT: Adoption of conservation tillage for cotton (*Gossypium hirsutum* L.) increased a modest 5.5 percent from 1992 to 1998 despite the evidence of the benefits to erosion control, soil health, and associated natural resources derived from conservation tillage. The Monsanto Centers of Excellence were established to evaluate the potential benefits of conservation tillage across a range of soils and climates. Our objective is to summarize the results from field-scale studies conducted at 12 Centers of Excellence sites in seven states from 1998 through 2002. No-tillage, strip tillage, reduced tillage and conventional tillage cotton production were evaluated in this study. All sites had a no-tillage and conventional tillage system, while eight of the 12 sites had a reduced tillage system and two of the 12 sites had a strip tillage system. Differences among tillage systems within a site did not show any significant effects on soil quality indicators. The variability within a site was quite large due to the limited number of samples collected at each location and the short-period of record covered by the study. Lint yield differences between no-tillage, strip tillage, reduced tillage, and conventional tillage systems were not significant. The 5-year average profit for the no-tillage system ranged from \$17 to \$164 ha^{-1} (\$7 to \$66 ac^{-1}) higher than the other 3 systems. Even though these differences were not significant because of large variations in environment, soil type, and production practices between sites and years the profit was always positive for no-till systems compared to other tillage systems. We conclude that farmers, crop consultants, and others should carefully consider overall profit rather than just crop yield when evaluating alternative tillage practices.

Keywords: Conventional tillage, cotton, no-till, strip till

The Conservation Technology Information Center (CTIC, 2002a) reported the percentage no-tillage cotton acres in southeastern United States (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia) increased 6.5 fold during the 1992 to 2002 period (CTIC, 2002a). In 1992, an estimated 4.4 percent of the cotton in the southeastern United States was no-till acres. The amount of no-till land increased 5.5 percent over the next six years. The next four years, land under no-till cotton production increased 18.8 percent. In 2002, a total of 28.7 percent of the land area was no-tilled (CTIC, 2002a). The primary reason for the increase in no-till cotton production can be attributed to the introduction of Round-up Ready® cotton in 1997 (Figure 1). Since 1998, the adoption rate for no-till has changed compared to the adoption rate prior to the introduction of Round-Up Ready® cotton in the southeastern United States (Figure 1).

The percentage of land with reduced tillage systems, increased from 9.1 percent to 14.3 percent during the same 11-year period (CTIC, 2002a). By definition, reduced tillage systems uses just enough full width tillage passes that disturb the soil surface with 15 to 30 percent of the residue remaining on the soil surface (CTIC, 2002b). Whereas, a conventional tillage system also uses full

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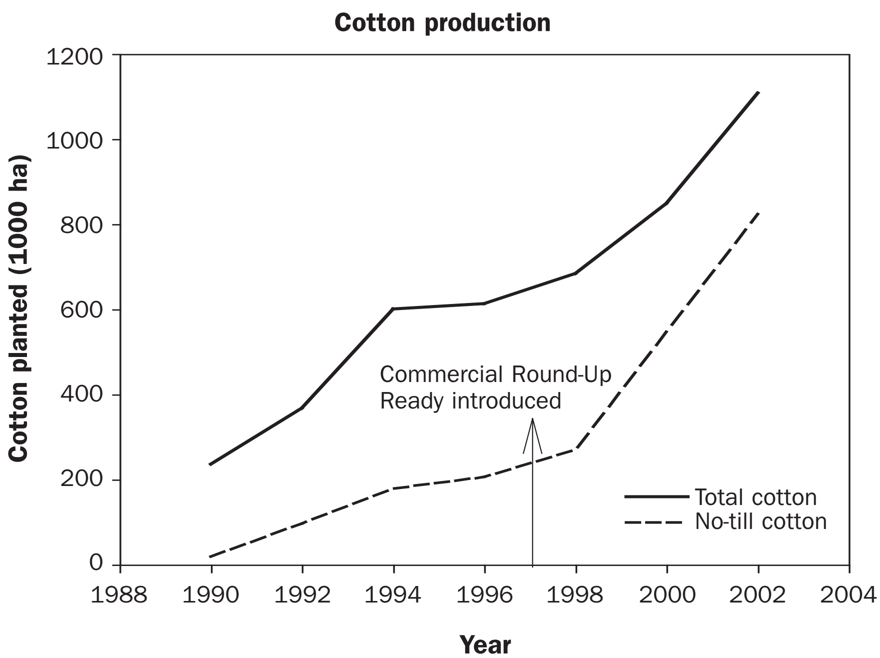
Figure 1

Land area in cotton production in the Southeastern United States and the adoption of No-till cotton production before and after Round-Up® cotton was introduced.



width tillage, but disturbs the entire soil surface and leaves less than 15 percent of the residue on the soil surface.

Conventional tillage system acres decreased from 83 percent to 52 percent during 1992 to 2002 (CTIC, 2002a). Other conservation tillage practices such as ridge till or mulch till systems increased 3.5 to 5.2 percent during the same time period. Approximately 34 percent of the total cotton land area in the southeastern United States practiced some type of conservation tillage system in 2002 (CTIC, 2002a).

Farmers in the Cotton Belt, in a recent Monsanto survey, cited many reasons for preferring conventional tillage for cotton (Bradley and Buman, 2001). The most common reasons included: 1) a belief that no-tillage does not work on all soil types; 2) the lack of equipment; 3) past experience; and 4) a general preference for cultivation. Also included in the survey were factors, which farmers claimed would encourage them to adopt conservation tillage. These included: 1) economics, 2) appropriate no-tillage equipment, 3) better yields, and 4) nothing.

Researchers have documented the success of various conservation tillage systems with regard to reducing erosion, improving soil health, and preserving natural resources. No-till and strip-till reduce soil erosion and chemical runoff, improve water infiltration, and increase residue cover, organic matter, earthworms, and other soil organism populations (CTIC, 2003). These two tillage systems also reduce labor and decrease the amount of equipment and fuel needed for crop production.

The documented benefits of conservation tillage, coupled with evidence of slow adoption, prompted the Monsanto Company to develop geographically-based, field-scale sites to demonstrate and evaluate various tillage practices. The Center of Excellence program was initiated in 1998 to collect and disseminate information regarding the impact of no-till, strip-till, reduced-till, and conventional till on crop production. The primary audience for this information was local farmers, crop consultants, agri-retail dealers, Natural Resources Conservation Service (NRCS) employees, and other professionals. Our objective for this analysis is to summarize the results from these field-scale studies, and to determine how tillage systems affect cotton yield and quality, soil properties, and economics of cotton production.

Figure 2

Locations of the Center of Excellence sites throughout the United States.

Table 1. Location and information about each Monsanto Center of Excellence site from which data was collected (1998 to 2002).

Location	Years	Soil type
Loxley, AL	1998-2002	Magnolia fine sandy loam; fine-loamy, mixed, semiactive, mesic Typic Paleudalfs
Buckeye, AZ	2001	Perryville sandy loam; coarse-loamy, carbonatic, hyperthermic Petronodic Haplocalcids Maripo sandy loam: coarse-loamy, mixed, superactive, calcareous, hyperthermic Typic Torrifluvents Laveen sandy loam; coarse-loamy, mixed, superactive, hyperthermic Typic Haplocalcids
Jonesboro, AR	1998-2001	Dundee fine sandy loam; fine-silty, mixed, active, thermic Typic Endoaqualfs
Mer Rouge, LA	1998-2002	Mer Rouge silt loam; mixed, superactive, thermic Typic Argiudolls
Leland, MS	1999-2001	Bosket very fine sandy loam; fine-loamy, mixed active, thermic Mollic Hapludalfs
Yazoo City, MS	2001-2002	Forestdale silt loam; fine, smectitic, thermic Typic Endoaqualfs
Bishopville, SC	1998-2001	Marlboro loamy sand; fine, kaolinitic Typic Paleudults
Cameron, SC	2001-2002	Norfolk loamy sand; fine-loamy, kaolinitic, thermic Typic Kandiudults
Brownfield, TX	2002	Amarillo series, Fine-loamy, mixed, superactive, thermic Aridic Paleustalfs
Halfway, TX	2001-2002	Pullman Clay Loam; Fine, mixed, superactive, thermic Torrertic Paleustolls
Robstown, TX	1999-2001	Victoria Clay; Fine, smectitic, hyperthermic Udic Haplusterts
Seymour, TX	2001	Miles sandy loam; fine-loamy, mixed, superactive, thermic Typic Paleustalfs

The cooperators in this study had no experience with no-till prior to this study.

Methods and Materials

General design. The Monsanto Center of Excellence project started in 1998 and is still in operation. The 12 sites evaluated for this study, (Figure 2) were distributed throughout the Cotton Belt and generally had a replicated large plot design to accommodate production size equipment (Table 1).

Each Center of Excellence site was divided into two or three equal tillage plots and randomized. Each of these plots was further subdivided into three or four sub-plots if the tillage treatments were replicated. The size of each sub-plot ranged from 0.5 to 2 ha (1.3 to 5 ac). Cotton production was evaluated using no-till, strip-till, reduced-till, and conventional till systems. Planter attachments such as coulters, row cleaner, or a combination of the two were commonly used when planting no-till cotton. The strips for the strip tillage system were created in the spring just prior to planting at the Loxley, Alabama site. The strip tillage unit at the Cameron, South Carolina site was placed between the tractor and planter (for a one pass operation or treatment). The conservation tillage and conventional tillage systems were defined as the predominant local fall and/or spring tillage practices. Two sites included no-tillage, strip tillage and conventional tillage. Eight sites included no-till, reduced till, and conventional till. The remaining two sites included only the no-tillage and the conventional tillage treatments.

This report focuses on data collected from 1998 through 2002. The entire data set was first segregated by short vs. long staple cotton type to try to reduce variability. The entire data set was then segregated by harvest method (picker vs. stripper). Neither segregation method reduced the variability among Center of Excellence locations or production years. Monthly rainfall variations from the 30-year monthly average were analyzed for a correlation with yield. No significant correlation between variation in monthly rainfall and yield when using analysis of variance (Neter et al., 1985).

The data for the sites that had replicated tillage plots were then analyzed using the Tukey method of multiple comparisons ($\alpha = 0.05$) (Neter et al., 1985). The data values for all Center of Excellence sites were then combined by tillage systems within each year and across all years. The combined data was then analyzed using the Tukey method of multiple comparisons ($\alpha = 0.05$).

Soil quality indicators. Composite samples from the 0 to 10- and 10 to 20-cm depth were collected in 2001 within each treatment by cooperators at 10 Center of Excellence sites and submitted to the National Soil Tilth Laboratory (NSTL) where the soil was analyzed using standard methods. Bulk density was estimated using a modified core method (Blake and Hartge, 1986), in which soil moisture content, determined by drying a sub sample of the cored soil at 105°C, was used to convert the total mass of the field-moist soil core to an oven-dry weight. Soil pH was measured in water using 5 g air dry soil and 5 ml deionized water in a 1:1 soil:water ratio (Watson and Brown, 1998). Water-stable macro-aggregates were determined using the methods described by Cambardella and Elliott (1993) and expressed as a percentage of the total soil in aggregates greater than 250 μm in diameter. Soil organic carbon (C), total nitrogen (N), and particulate organic matter C were determined using the air-dried 2-mm-sieved soil. Total C (after removal of carbonates with 1 M H_2SO_4) and N were measured using dry combustion methods in a Carlo-Erba NA1500 NCS* elemental analyzer (Haake Buchler Instruments, Paterson, New Jersey). Particulate organic matter was isolated and quantified according to methods described by Cambardella and Elliott (1992) using dry combustion. Phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) concentrations were measured by inductively coupled plasma emission spectroscopy after extraction with the Mehlich III solution (Mehlich, 1984). Copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were also determined by inductively coupled plasma emission spectroscopy after extraction with diethylenetriaminepentaacetic (DTPA) acid as discussed by Whitney (1998).

After evaluating tillage effects for each indicator, index values and an overall soil quality index were calculated using the Soil

Management Assessment Framework for each site and depth increment. Bulk density, pH, Mg, C, and P values were transformed with non-linear scoring curves to create unit-less scores that reflect performance of soil functions (Andrews et al., 2002; Cambardella et al., 2004). The shape of each scoring curve is typically some variation of a bell-shape ('midpoint optimum'), sigmoid with an upper asymptote ('more is better'), or sigmoid with a lower asymptote ('less is better') (Karlen and Stott, 1994). Each curve was adjusted for geographic location, thus accounting for inherent organic matter class (taxonomic suborder), texture, climate, sampling time, mineralogy, region, slope, and analytical method for P. Individual indicator scores and the overall additive index were interpreted assuming higher values indicate better soil quality. A more complete discussion of the theory, development process, and testing of the Soil Management Assessment Framework is found in Andrews et al. (2004).

Data for each indicator and the overall soil quality index were analyzed statistically by site, and by depth, using a general linear model procedure (SAS Institute, 1992). However, because of the experimental design and limited number of samples, it was not possible to differentiate among all of the treatments (e.g. corn vs. soybean, strip-till vs. no-till, or conventional tillage vs. fast-start). The treatments were therefore classified as either conventional or no-till with 'strip-till' being grouped with "no-till" and 'fast-start' being grouped with "conventional" tillage.

Weather. Daily air temperature and rainfall were downloaded from the Midwest Regional Climate Center for the National Oceanic and Atmospheric Administration's (NOAA) weather station nearest each site. These data were close to each site so no on-site data were recorded for this study.

Production costs. Fertilizer rate, amount, and timing were constant across tillage treatments within each Monsanto site, but varied among Centers. Depending upon location, fertilizer was applied either in the fall, spring, at planting, post-emergence, or a combination of these timings.

The cotton variety and planting rates at each Center of Excellence site was representative of those used in the area around each site. Each tillage treatment had the same variety at each location planted. All cotton varieties planted in the studies contained Roundup Ready® and Bollgard® technology. The desired plant population for cotton was constant for all tillage treatments at a given site, but varied from site to site. Herbicides were applied as needed following programs that were typical for each Center site, but were primarily glyphosate based applications.

Seed, fertilizer, pesticide, defoliant, and irrigation cost information were supplied by the producer. Operation costs were determined using the average custom rate for tillage, fertilizer application, planting, pesticide application, harvest, and ginning in the state where the Center of Excellence site was located. The operation costs accounted for fuel, labor, depreciation, maintenance, and repairs. A six-month, 10 percent interest fee was calculated for all input expenses incurred from mid-April to harvest the following fall. The production cost for a tillage treatment was calculated by summing seed, fertilizer, pesticide, operation, hauling, and interest expenses each year. These costs were averaged across all years and Center of Excellence sites. Land rent was not included in the production cost because of the large variability from site to site.

Crop yield. Cotton lint yields were measured for each plot at the Center's site. Cotton seed at some Center sites was added to the plot income and the ginning cost was added to the operations cost, whereas, at other sites cotton seed was used to offset the ginning cost.

Crop profit. Income was calculated by multiplying the cotton yields (kg ha^{-1}) by \$1.43 kg^{-1} (\$0.65 lb^{-1}) in 1998-2000, \$1.32 kg^{-1} (\$0.60 lb^{-1}) in 2001 and \$1.54 kg^{-1} (\$0.70 lb^{-1}) in 2002. The prices do not include (any) commodity payments (USDA-government payments) and were typical of the study period. Profit for each treatment was calculated by subtracting the appropriate production costs from the income. Profits for each tillage system were statistically analyzed using Center of Excellence sites within a year as replicates.

Crop break even selling price. Break even selling prices were calculated for each tillage system by dividing the five-year average production cost by the five-year average yield. This method was selected because of the variation in price among years and locations. Determining the selling price required to recover the production costs provided a way of normalizing among the locations. The procedures used by Duffy and Smith (2004) were used in these analyses for the different rotations and sites.

Five year crop profit. The five-year profit for cotton was calculated by summing the average yearly profit values. This method provides a way of estimating the total profit of each tillage system for the duration of the study.

Results and Discussion

Soil quality indicators. Very few statistically significant differences ($P \leq 0.1$) were found among the soil quality indicators measured for the 0 to 10- and 10 to 20-cm depth increments at the Center of Excellence cotton production sites. Soil pH was higher in no-till than conventional till plots at the Seymour, Texas site (5.6 vs. 4.8 and 5.5 vs. 5.0 for the 0 to 10 and 10 to 20 cm depth increments, respectively, but the difference was statistically significant only for the 10 to 20 cm increment). Extractable P in the surface 10 cm showed significant tillage effects for the Robstown, Texas and Seymour, Texas sites, but at Robstown no-till plots were higher while at Seymour the conventional treatment was higher. Extractable P concentrations in the 10 to 20 cm depth increment were low (<18 μg g^{-1}) at both locations.

The soil quality index values calculated using the Soil Management Assessment Framework were equal or slightly higher for no-till than conventional till treatments for both depth increments at the seven sites where soil quality data were collected, but the only one approaching statistical significance ($P = 0.11$) was the Yazoo County, Mississippi site. On a scale of 0 to 100, the overall soil quality index values for conventional and no-till treatments averaged 72 and 74 for the 0 to 10 cm increment or 70 and 71 for the 20 cm depth increment, respectively. Individual indicator scores were lowest for total organic C suggesting that soil quality may be improved at these sites if the organic C content could be increased. The slightly higher total organic C concentrations in the no-tillage plots for all sites except Half-Way, Texas (data not presented) suggest this may be possible if no-tillage practices are continued for a longer period of time. However, variability associated with the non-replicated field plot design, the relatively short length of time that no-till practices had actually been used at these sites (greater than or equal to three years), and the limited number of soil samples (~ 45 for each depth from the seven sites) prevent the development of a trend in these analyses.

Weather. Monthly growing-degree days (base 15°C/60°F) were similar to the 30-year average when averaged across sites. The yearly

Table 2. Yearly and 30-year average rainfall for the 12 Monsanto Center of Excellence sites.						
	Years					30-year
Location	1998 (mm)	1999 (mm)	2000 (mm)	2001 (mm)	2002 (mm)	average (mm)
Loxley, AL	2379	1414	1091	1577	1712	1728
Jonesboro, AR	1187	747	854	1396		1189
Buckeye, AZ				140		213
Mer Rouge, LA	1425	1311	1314	1783	1579	1468
Leland, MS		1151	1484	1810		1346
Yazoo City, MS				1525	1629	1522
Bishopville, SC	1320	1054	984	654		1160
Cameron, SC				906	995	1233
Brownfield, TX					501	480
Halfway, TX				537	616	570
Robstown, TX	848	712	797	851		832
Seymour, TX				837	806	701

rainfall varied from 44 percent below to 38 percent above the 30-year average rainfall (Table 2). The yearly rainfall total in 1998 and 1999 at the Loxley, Alabama site was 18 and 37 percent below the 30-year average rainfall, respectively. The South Carolina sites had a yearly rainfall total that was nine to 44 percent lower than the 30-year average from 1999 to 2002. Also, the yearly rainfall at the Mer Rouge, Louisiana and Jonesboro, Arkansas Center of Excellence sites were from 10 to 37 percent below the 30-year average in 1999 and 2000. Below normal rainfall amounts for the study period potentially masked tillage differences because water became the primary limiting factor in cotton growth and yield.

Even though a reduced soil water evaporation rate has been noted in no-till systems the impact was not significant to overcome the overall lack of rainfall at the sites during the Center of Excellence study. Lack of rainfall was the main factor contributing to yield variability because when we sorted the sites by seasonal precipitation amounts the variability within and among sites remained. The short duration of the use of no-till and reduced tillage systems in these sites did not affect the soil water holding capacity through changes in the soil organic matter. The effect of the increased residue on soil water evaporation was not sufficient to overcome the extremely dry conditions at the sites.

Cotton production cost. All 12 Center of Excellence sites included in this study evaluated no-till and conventional till cotton production systems. The reduced tillage system was included at eight of the 12 sites, whereas the strip till system was included at only two of the 12 sites. Results for these three groups were different and are discussed separately. The no-till/conventional till group includes all 12 Center of Excellence sites. The reduced till group includes eight sites that have a reduced tillage system as well as no-till and conventional till systems. The strip till group includes two sites with strip till system, as well as no-till and conventional till systems.

The five-year average production cost for no-tillage treatment was \$67 ha^{-1} (\$27 ac^{-1}) lower than the conventional tillage treatment in the no-till/conventional till group (Table 3). In the reduced tillage group the five-year average production cost for no-till treatment was \$44 and \$68 ha^{-1} (\$18 and \$28 ac^{-1}) lower than the reduced tillage and conventional tillage treatments, respectively (Table 3). Within the strip till group, the no-till treatment was \$11 and \$83 ha^{-1} (\$4 and \$34 ac^{-1}) lower than the strip till and conventional till treatments, respectively (Table 3). Differences in production costs were due to reduced herbicide and tillage costs within the different groups. A common cost factor for all sites was the shredding cotton stalks from the previous growing season; many sites forgot to add this cost into total operation cost. The cost of stalk shredding was deducted from all operation cost analysis.

Conventional tillage treatment required, on average, six tillage passes per growing season in the no-till/conventional comparison.

Table 3. Five-year average production cost for tillage systems for cotton sites across the Monsanto Center of Excellence study for 1998 to 2002.

		Production component cost (\$ ha^{-1})					
Tillage group	Tillage system	Seed	Fertilizer	Pest control	Operation	Interest	Total
No-till/conventional till group	No-tillage	99.84	109.34	282.27	426.32	45.48	963.25
	Conventional tillage	100.55	109.03	266.50	505.74	48.58	1030.40
Reduced till group	No-tillage	103.53	89.91	297.14	412.88	44.40	947.86
	Reduced tillage	106.00	89.98	293.85	456.01	46.37	992.21
	Conventional tillage	105.93	89.31	283.48	490.05	47.50	1016.27
Strip till group	No-tillage	104.64	160.06	239.87	469.95	48.73	1023.25
	Strip tillage	104.64	160.23	241.32	479.01	49.26	1034.46
	Conventional tillage	104.64	160.23	227.60	561.50	52.70	1106.67

Multiply \$ ha^{-1} by 0.405 to obtain \$ $ac.^{-1}$

Table 4. Cotton lint yield for the Monsanto Center of Excellence sites for the 1998 to 2002 period.

		Yield (kg ha^{-1})*					
Tillage group	Tillage system	1998	1999	2000	2001	2002	Average
No-till/conventional till group	No-till	881 (787)†	833 (743)	775 (705)	862 (792)	1044 (940)	879 (793)
	Conventional till	852 (761)	892 (796)	797 (730)	859 (795)	948 (838)	870 (784)
Reduced till group	No-till	762 (214)	748 (227)	798 (228)	781 (333)	1243 (43)	868 (216)
	Reduced till	743 (278)	695 (184)	759 (219)	782 (343)	1246 (129)	845 (226)
	Conventional till	744 (208)	785 (251)	826 (299)	762 (355)	1202 (52)	864 (192)
Strip tillage group	No-till	1157 (165)	1381 (160)	855 (95)	978 (193)	534 (302)	981 (183)
	Strip till	997 (98)	1301 (166)	814 (87)	972 (172)	502 (288)	917 (158)
	Conventional till	1034 (56)	1471 (190)	786 (130)	909 (202)	433 (274)	927 (169)

* Multiply kg ha^{-1} by 0.89 to get lb ac.$^{-1}$

† Standard deviation among the Center of Excellence sites.

In the reduced tillage group, reduced tillage treatment and conventional tillage treatment required on average three and six tillage passes per growing season, respectively. Whereas, in the strip till group, strip-till treatment and conventional till treatment required one and five tillage passes, respectively. The Jonesboro, Arkansas, Loxley, Alabama, Robstown, Texas, Halfway, Texas, Seymour, Texas, and Brownfield, Texas sites required additional pre-emergence herbicide applications to control early season weeds in no-tillage, strip-tillage, and reduced tillage treatments. These additional tillage passes and herbicide treatments added to the production costs in the systems compared to no-till.

Cotton-lint yields. Lint yield is the first variable that producers use to compare differences among tillage systems; however, lint yield is only one component to determine profitability. Lint yield among years was not significantly different for the no-till/conventional till, reduced tillage or strip tillage groups (Table 4). When aggregated to a five-year average the differences among tillage systems remained insignificant. Annual differences between the 2 tillage treatments in the no-till/conventional till group ranged from 3 to 96 kg ha^{-1} (3 to 86 lb ac^{-1}). The large yield differences between years for both the conventional tillage and no-tillage treatments at the Bishopville, South Carolina; Cameron, South Carolina; Jonesboro, Arkansas; and Loxley, Alabama sites were presumably because of below normal rainfall at each site. Rainfall variability was more dominant on lint yield than tillage systems and when we attempted to adjust for either precipitation- or growing-degree day differences this did not resolve the yield differences. The lack of significant differences between the tillage comparisons was probably the result of large variations in weather, soil type, and production among the 12 Center of Excellence sites. However, the lack of significance can be considered a positive when showing that no-till practices did not decrease yields and were generally always positive compared to other tillage systems.

For the reduced tillage group, the five-year average lint yield for conventional tillage treatment was not significantly higher than the reduced tillage or no-tillage treatments (Table 4). Yearly yield differences among reduced till, no-till, and conventional till treatments during the 1998 to 2002 time period, ranged from 1 to 90 kg ha^{-1} (1 to 80 lb ac^{-1}). In the strip tillage group, the five-year average lint yield for the no-tillage treatment was not significantly higher than the conventional tillage and strip tillage treatments. Yearly differences among the three tillage treatments within the strip tillage group ranged from 3 to 170 kg ha^{-1} (3 to 152 lb ac^{-1}). Once again, the large yield differences between years within a specific tillage treatments for both the reduced and strip tillage treatments at the Bishopville, South Carolina; Cameron, South Carolina; Jonesboro, Arkansas; and Loxley, Alabama sites were presumably because of below normal rainfall at each site.

Lint yield differences measured in this study were similar to those found by others. For example, Kennedy and Hutchinson (2001) reported that no-tillage had a five and 16 percent higher yield than the conventional till and reduced till systems, respectively. Hoskinson and Howard (1992) and Boquet et al. (2004) also showed a five and a nine percent higher lint yield in a no-tillage system than in a conventional tillage system, respectively. Under a non-residual herbicide system in a three-year study, no-till had a five percent higher yield than did the spring strip tillage and the conventional tillage systems (Atwell et al., 2001). Holman (1998) in a two-year study and Daniel et al. (1999) in a three-year study found that cotton yields were not affected by tillage practices. Burmester et al. (1993) in a five-year study found that a no-tillage had a 10 percent lower lint yield than a conventional tillage system.

Cotton profit. Comparisons of profit within any of the tillage groups did not show a signficant difference for no-till compared to any form of tillage (Table 5). The encouraging aspect of these analyses was that the no-till profit was always higher than the other tillage systems. The \$44 to \$218 ha^{-1} (\$18 and \$88 ac^{-1}) difference between the no-tillage and the conventional tillage treatment in four of five years for the no-till/conventional till group was not significantly different (Table 5). The five-year average profit for the no-tillage treatment was not significantly higher than other tillage treatments in any of the comparison groups.

Profit should be the dominant factor when making decisions regarding adoption of tillage practices. Lower production costs (\$67 to \$84 ha^{-1}) for no-tillage can offset a 47 to 59 kg ha^{-1} (42 to 53 lb ac^{-1}) decline in yield when compared to conventional tillage. Similarly, lower production costs for strip-tillage (\$73 ha^{-1}) and reduced tillage (\$24 ha^{-1}) can offset approximately 51 kg ha^{-1} (46 lb ac^{-1}) and 17 kg ha^{-1} (15 lb ac^{-1}) decline in yield, when compared to conventional tillage and still obtain a similar profit, respectively. Atwell et al. (2001) reported that no-tillage had a \$104 ha^{-1} and \$180 ha^{-1} (\$42 ac^{-1} and \$73 ac^{-1}) higher profit than a strip tillage and conventional tillage system, respectively, in the first three years of a study. Smart and Bradford (1999) reported that a no-till system had a \$215 ha^{-1} (\$87 ac^{-1}) higher profit than a conventional tillage system. Smart et al. (2001) found that conservation till had a \$121

Table 5. Profit for the cotton production systems for the 1998 to 2002 period across the Monsanto Center of Excellence sites.

Tillage group	Tillage system	Profit ($ ha^{-1})*					
		1998	1999	2000	2001	2002	Average
No-till/Conventional till group	No-till	261 (1125)†	271 (1062)	248 (1008)	285 (1045)	653 (1448)	344 (1138)
	Conventional till	173 (1088)	293 (1138)	199 (1044)	205 (1047)	435 (1291)	260 (1122)
Reduced till group	No-till	77 (398)	80 (164)	272 (400)	156 (454)	832 (199)	260 (324)
	Reduced till	31 (298)	169 (360)	272 (429)	90 (470)	715 (80)	243 (225)
	Conventional till	56 (307)	105 (325)	205 (327)	73 (441)	754 (66)	225 (310)
Strip tillage group	No-till	555 (236)	852 (229)	205 (136)	495 (255)	-117 (466)	398 (265)
	Strip till	321 (112)	726 (258)	128 (125)	461 (228)	-160 (445)	295 (229)
	Conventional till	339 (72)	852 (272)	-38 (186)	334 (267)	-318 (423)	234 (244)

* **Multiply $ ha^{-1} by 0.405 to get $ ac.$^{-1}$**

† **Standard deviation across the Center of Excellence sites.**

ha^{-1} ($49 ac^{-1}) lower input cost and equal or greater economic returns than a conventional moldboard plow tillage system. The results from this study confirm the results from those studies and represent a larger cotton production area.

Break even selling price. The break even selling price was lower for no-till than for the strip till, reduced till, and conventional till, meaning that a producer could receive a lower price for their lint and still make a higher profit with no-tillage system. For the no-till/conventional till group, the five-year average break-even cost were $1.10 and $1.18 kg^{-1} ($0.50 and $0.54 lb^{-1}) for no-till and conventional till, respectively. The five-year average break-even costs for the reduced tillage group were $1.12, $1.15, and $1.17 kg^{-1} ($0.51, $0.52, and $0.53) for the no-till, reduced till, and conventional till treatments, respectively. For the strip tillage group, the five-yr average break even costs were $1.15, $1.24, and $1.42 kg^{-1} ($0.52, $0.56, and $0.64 bu^{-1}) for no-till, strip-till, and conventional till, respectively.

Five year crop profit. Across the five years of this study, the no-till system consistently produced a higher profit compared to the other tillage systems. For the no-till/conventional till group, the five-year profit for the no-till treatment was $400 ha^{-1} ($162 ac^{-1}) higher than the conventional till treatment (Table 6). For the reduced till group, the five-year profit for the no-till treatment was $85 ha^{-1} ($34 ac^{-1}) and $175 ha^{-1} ($71 ac^{-1}) higher than the reduced tillage and conventional tillage treatments, respectively. For the strip till group, the five-year profit for the no-till treatment was $515 ha^{-1} ($209 ac^{-1}) and $820 ha^{-1} ($332 ac^{-1}) higher than the strip-till and conventional till treatments, respectively.

Summary and Conclusion

Establishment of the Monsanto Center of Excellence sites has provided important and useful field-scale information regarding tillage practices for cotton production. High variability in local environmental conditions, soil type, and variations in specific management practices at individual sites resulted in few statistically significant differences but very consistent trends. A positive result from these studies is that no-till did not decrease yields and at all sites produced lint yields that were in the upper range of observed yields in spite of the variation in rainfall, soils, and production practices. Lint yield should not be the dominant factor used to evaluate tillage systems for cotton. Lower production costs ($67 to $84 ha^{-1}) for no-till can offset a 47 to 59 kg ha^{-1} (42 to 53 lb ac^{-1}) decline in yield when compared to conventional till. Similarly, lower production costs for strip-till ($73 ha^{-1}) and reduced till ($24 ha^{-1}) can offset approximately 51 kg ha^{-1} (46 lb ac^{-1}) and 17 kg ha^{-1} (15 lb ac^{-1}) decline in yield, when compared to conventional till and still obtain a similar profit, respectively. Cotton lint yield was not significantly affected by the tillage practices implemented in this study. The numerically higher profits in four of five years for the no-till cotton systems, when compared to the conventional till systems, represent a positive component in comparing tillage systems. Also, the environmental benefits derived from reduced till practices, increase the overall value of no-till production systems.

Table 6. Overall profit for the cotton production systems for the 1998 to 2002 period across the Monsanto Center of Excellence sites.

Tillage group	Tillage system	Overall five-year profit ($ ha^{-1})* 1998-2002
No-till/ Conventional till group	No-till	1700
	Conventional till	1300
Reduced till group	No-till	1300
	Reduced till	1215
	Conventional till	1125
Strip till group	No-till	1900
	Strip till	1475
	Conventional tillage	1170

* **Multiply $ ha^{-1} by 0.405 to get $ ac.$^{-1}$**

Footnote

*Mention of a specific tradename or product does not imply preferential treatment or recommendation.

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